Controlled Humidity Protection

Current DoD Snapshot

LG101L7/JUNE 2003

By Andrew Timko and Owen R. Thompson

This paper summarizes current use of controlled humidity protection (CHP) within the Department of Defense. The appendix provides background information on the effects of moisture and relative humidity on weapon systems as well as the results of various CHP evaluations.

Moisture degradation of DoD weapon systems and equipment represents an important cost of ownership issue. Current costs to DoD are difficult to establish, but estimates of moisture-induced degradation range between $3 billion and $12 billion annually.[1,2,3] Numerous non-financial effects also exist, the most important being the reduced readiness and sustainability of DoD weapon systems and equipment. There are also environmental consequences, such as from the use of hazardous chemicals to treat corrosion.

BACKGROUND

Traditional moisture-mitigating techniques include material and design changes as well as physical barriers (such as paint, lubricants, and top covers) that separate the moisture from the item. Recent remarks by Mr. Michael Wynne, Acting Under Secretary of Defense for Acquisition Technology and Logistics (USD[AT&L]), to the U.S. Army Corrosion Summit focused on system modernization, use of new technologies in the application of barriers (e.g., the high-velocity oxygen fuel [HVOF] spray process that is expected to be applied to

[1] U.S. Army Center for Army Analysis briefing Aviation Systems Performance Readiness and Corrosion Study (ASPRCS), presented at the U.S. Army Corrosion Summit, March 2002.

[2] NCI information Systems, *Study to Determine the Annual Direct Cost of Corrosion Maintenance for Weapon Systems and Equipment in the United States Air Force*, was prepared for the Air Force Corrosion Program Office, February 6, 1998, p. 2.

[3] Michael Wynne, Acting Under Secretary of Defense (Acquisition Technology & Logistics), *Corrosion: The Path Ahead*, U.S. Army Corrosion Summit, February 12, 2003, p. 3.

the Joint Strike Fighter), and material substitution (e.g., high-density polyethylene [HDPE], a nonmetallic material used as a substitute for metal).[4]

An alternative approach—controlled humidity protection—is designed to control the moisture in the air itself, specifically relative humidity (RH). By extracting moisture from the air, RH can be reduced to a level at which damaging moisture cannot form. This processed air is recirculated into or around the item, equipment, or system being protected.[5,6]

Weapon systems and equipment in storage (such as excess or retired systems, pre-positioned equipment, and war reserve materiel) are currently protected to the extent possible. The primary focus of this paper, however, is the protection of weapon systems and equipment in mission-ready status. In this context, CHP is viewed as a maintenance technology, not a storage technology.

There are four categories of CHP systems employed within DoD. The categories differ in a number of characteristics, including the amount of time the weapon systems or end items remain in CHP, whether maintenance requirements are deferred, and the number of weapon systems or end items that can be protected by a single CHP system. The four CHP system categories are long-term protection (LTP); modified long-term protection (MLTP); operational protection (OP); and Single Vehicle Environment Stabilization System™ (SVESS™).[7] Figure 1 depicts examples of the four CHP categories and Table 1 identifies the primary characteristics of the four categories.

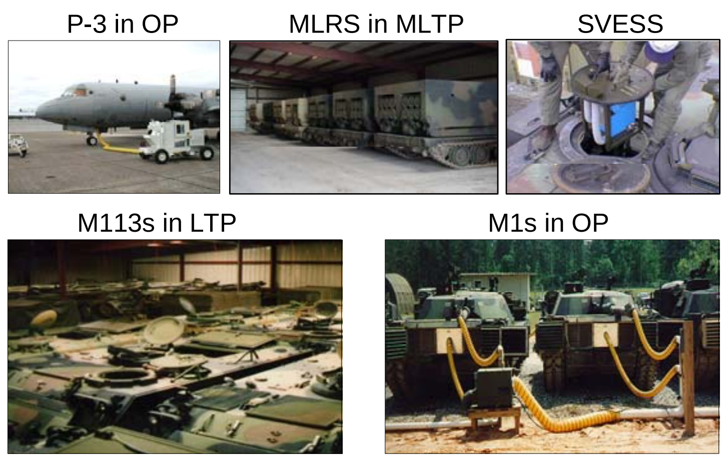


Figure 1.
CHP Systems

[4] Michael Wynne, Acting Under Secretary of Defense (Acquisition Technology and Logistics), *Corrosion: The Path Ahead*, U.S. Army Corrosion Summit, February 12, 2003, pp. 4–6.

[5] U.S. Navy, *NAVAIR Technical Manual 15-01-500*, Section I (Introduction), pp. 6-1 and 6-2, Section II (Static Dehumidification), p. 3-2.

[6] Within the Army, the acronym CHP refers to controlled humidity preservation. Other services may use different terms to describe the controlled humidity protection system.

[7] Single Vehicle Environment Stabilization System (SVESS) is a trademark of Logis-Tech, Inc.

Table 1. Characteristics of CHP Systems

	LTP	MLTP	OP	SVESS
Type of CHP system	Shelter	Shelter	External dehumidifier connected to weapon system/end item	Dehumidifier that replaces the hatch on a ground combat vehicle
Protects the weapon systems' external structure/hull	Yes	Yes	No	No
Protects the weapon systems' internal systems	Yes	Yes	Yes	Yes
Weapon system capacity of CHP system	See note	See note	Combat vehicles: 20 Aircraft: 1 or 2	1 weapon system
Duration of vehicles in CHP	1–3 years	90 days to 1 year	1 or more days	1 or more days
Authorization to defer scheduled maintenance	Yes	Yes	No	No

Note: Shelters normally range from 5,000 sq. ft. to 30,000 sq. ft. For example, approximately 25 M1 tanks can be placed in a 10,000 sq. ft. shelter. Shelters are sized to meet the unit's CHP requirements.

CHP has been extensively evaluated and is now widely applied by many nations as a maintenance technology for operational weapon systems. Within DoD, the Army National Guard (ARNG) has been in the forefront in the application of CHP to its weapon systems and end items. With the exception of the ARNG, however, CHP has not been broadly implemented by the military services.

CURRENT EFFORTS

Each of the services is using CHP to protect a segment of their weapon system inventories. For example, the Army has tracked and wheeled vehicles in nearly 50 MLTP shelters in Qatar, the Navy has 16 P-3s in OP at 6 different locations, the Air Force has its two VC-25s (Air Force One) in OP at Andrews AFB, and the Marine Corps has assault vehicles in OP at Marine Corps Logistics Base, Albany. Overall, DoD's current CHP capacity can protect roughly 6,000 weapon systems in OP and nearly 7,000 weapon systems in MLTP/LTP.[8] The majority of the weapon systems (and end items) in CHP belong to the ARNG—approximately 98 percent of the weapon systems in OP and about 64 percent of the weapon systems in MLTP/LTP. Table 2 depicts, by service or component, the category of CHP; the number of CHP locations; type of equipment in CHP; the number of CHP shelters or systems in use; and an approximate weapon system capacity (aircraft or M1 tank equivalents) of existing CHP systems and shelters.[9]

[8] Calculation of the estimates is explained at the end of Table 2.

[9] Primary data sources were the Army National Guard, Logis-Tech, Inc., and CALIBRE Systems, Inc.

Table 2. Estimates of DoD Systems in CHP

Service or component	Type of CHP	No. of locations	Equipment in CHP	No. of CHP systems or shelters	Estimated CHP system capacity[a]
Army	MLTP	1	Wheel and track vehicles	49 shelters	1,225[a]
ARNG	OP	60	M1, BFV, MSE, M109A6, FF radar	293 systems	5,860
ARNG	MLTP	79	M1, BFV, M109A6, Avenger, Patriot, FF radar, engineering equipment, ROWPU, wheeled vehicles	129 shelters	3,225[a]
ARNG	LTP/MLTP	9	M1, M113, MLRS, engineering equipment, field artillery, other miscellaneous equipment	40 shelters	1,000*
ARNG	LTP	5	M1, BFV, MLRS, ROWPU	5 shelters	125[a]
ARNG	SVESS	2	M1, M109A6	8 systems	8
USAR	MLTP	3	Engineering equipment and miscellaneous wheel vehicles	3 shelters	75[a]
Navy	OP	6	P-3 aircraft	16 systems	32 aircraft
Navy	MLTP	2	Miscellaneous aircraft components	3 shelters	75[a]
Navy	MLTP	4	Aircraft miscellaneous support equipment	4 shelters	100[a]
Navy	MLTP	3	Miscellaneous equipment, including radio, electronic, and ship support	13 shelters	325[a]
USAF	OP	1	VC-25 (Air Force 1)	1 shelter	2 aircraft
USMC	OP	2	Light attack and amphibious assault vehicles	4 systems	80
USMC	MLTP	2	Miscellaneous wheel and track	17 shelters	425[a]
USMC	MLTP	2	AV-8B Harrier and V-22 Osprey	4 shelters	100[a]
USMC	MLTP	3	Metrological measuring sets/Fire Finder Radar	3 shelters	75[a]

[a] This information attempts to “normalize” the CHP capacity of existing LTP and MLTP shelters. Because the shelters vary in size (normally ranging from 5,000 to 30,000 sq. ft.) and because the user can vary the type and quantities of individual weapon systems or end items inside the shelters, it is impossible to precisely list the systems currently in CHP. To illustrate the approximate CHP capacity, however, we assumed each shelter is 10,000 sq. ft. and all of the vehicles in CHP are M1s (which require ~400 sq. ft. each). The numbers identified represent the approximate number of M1s that could be accommodated in existing CHP shelters (if they average 10,000. sq. ft. each). Other assumptions are as follows:

- For OP CHP on-ground combat systems, each system can accommodate 20 vehicles; therefore, that is the quantity listed.
- For OP CHP on aircraft, each system can support two aircraft therefore that is the quantity listed.
- For SVESS, each CHP system can support one weapon system.

Separate sections detailing the ARNG and the other service CHP programs follow. The ARNG is presented separately because they possess the majority of CHP systems.

Army National Guard

By any measure, the Army National Guard possesses the most significant CHP capability within DoD. About 500 CHP systems or shelters are currently in place at nearly 150 locations, with the capability to protect more than 10,000 weapon systems and end items. At the completion of their CHP fielding period (estimated to be in 2007), the ARNG expects to have 25 percent of their total ground fleet (that is eligible for protection) in some form of CHP. In addition, of the combat vehicles and mobile subscriber equipment (MSE) that can be preserved via the OP systems, 75 percent of that total will be in an OP line. As an example, Figure 2 shows M1 tanks in OP.

Figure 2. ARNG M1s in OP

Nearly 500 CHP systems are currently fielded by the ARNG. Figure 3 illustrates the categories of weapon systems and end items that are being protected. Figure 4 depicts the number of ARNG CHP systems by category—current and planned—through 2007.

Figure 3. Weapon System and End Item Mix Currently in ARNG CHP

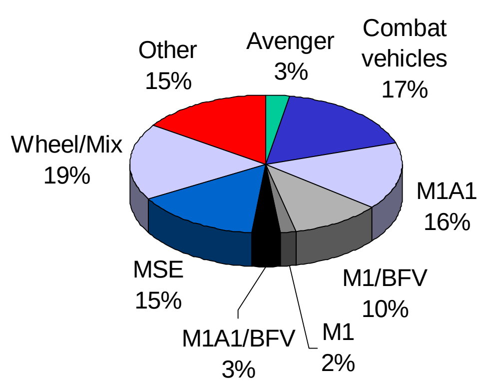
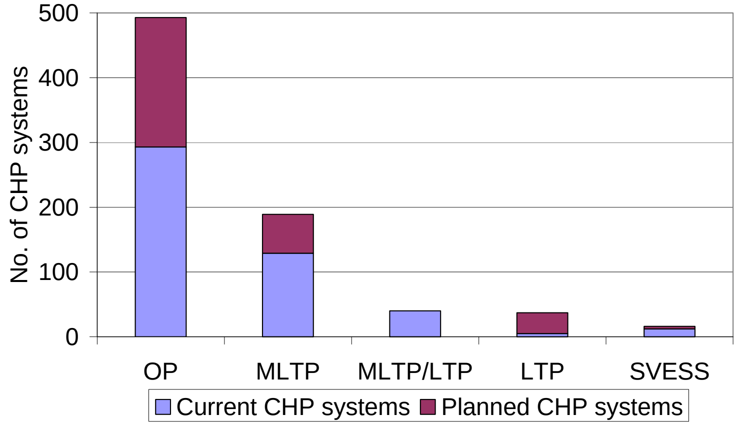


Figure 4. ARNG CHP Systems by Category



The benefits to the ARNG were recently calculated under procedures established by the Army's Cost and Economic Analysis Center. An economic analysis of their CHP program identified a potential for benefits in the range of $1.2 billion during the economic life of that program (through FY07). Empirical data showed a 9-to-1 benefit-to-investment ratio could be expected.[10] The economic benefits (cost avoidance) are the total of man-hour offsets and class IX spares. Additional benefits that cannot yet be quantified include increased readiness, reduction of maintenance backlog, and reduced class IX transportation costs.

Other DoD Services and Components

The ARNG's CHP program and the active Army's 49 MLTP shelters in Qatar account for approximately 90 percent of current CHP applications within DoD. While each of the services is currently employing CHP to protect weapon systems or end items, CHP is targeted to specific, and relatively limited, requirements. Table 3 depicts the principle DoD weapon systems and end items (excluding the ARNG) currently protected in specific CHP systems/shelters. Figure 5 illustrates the Marine Corps V-22s in OP.

Figure 5. USMC V-22s in OP at New River, NC

[10] Controlled Humidity Preservation Program, *Mid-Life Cycle Economic Analysis*, "Executive Summary," CALIBRE Systems, Inc., February 2003.

Table 3. Principle DoD CHP Applications (Excluding the ARNG)

Service	Protection type	Location	Weapon systems and equipment	CHP shelters or aircraft
Army	MLTP	Qatar	Wheel and track vehicles	49 shelters
USAR	MLTP	Fort Dix, NJ	Engineering equipment	1 shelter
USAR	MLTP	Fort McCoy, WI	Engineering equipment	1 shelter
USAR	MLTP	Spinelli Barracks, Germany	Miscellaneous wheel vehicles	1 shelter
Navy	MLTP	North Island, CA	Miscellaneous aircraft components	2 shelters
Navy	MLTP	NSA Jacksonville, FL	Miscellaneous aircraft components	1 shelter
Navy	MLTP	NAS Atlanta, GA	Aircraft MSE	1 shelter
Navy	MLTP	NAS Belle Chase, LA	Aircraft MSE	1 shelter
Navy	MLTP	NAS Andrews, MD	Aircraft MSE	1 shelter
Navy	MLTP	NAS Brunswick, ME	Aircraft MSE	1 shelter
Navy	MLTP	Charleston, SC	Radio/electronic equipment	6 shelters
Navy	MLTP	JRTC, Ft. Worth, TX	Miscellaneous equipment	6 shelters
Navy	OP	NAS Whidbey Island, WA	P-3	3 aircraft
Navy	OP	Bahrain	P-3	2 aircraft
Navy	OP	Greece	P-3	3 aircraft
Navy	OP	Spain	P-3	5 aircraft
Navy	OP	Misawa, Japan	P-3	1 aircraft
Navy	OP	Kadena, Japan	P-3	2 aircraft
Navy	MLTP	Sasebo, Japan	Miscellaneous ship support equip	1 shelter
USAF	OP	Andrews AFB, MD	VC-25 (Air Force 1)	2 aircraft
USMC	OP	MCLB Albany, GA	LAV and AAV	2 shelters
USMC	OP	Camp Lejuene, NC	LAV	2 shelters
USMC	OP/MLTP	MCAS New River, NC	V-22 Osprey	1 shelter
USMC	MLTP	Camp Pendleton, CA	MMS/fire finder radar	1 shelter
USMC	MLTP	MCLB Albany, GA	Miscellaneous wheel and track	15 shelters
USMC	MLTP	MCAS Cherry Point, NC	AV-8B Harriers	3 shelters
USMC	MLTP	Camp Lejuene, NC	Miscellaneous wheeled vehicles	2 shelters
USMC	MLTP	JRTC, Ft. Worth, TX	MMS/fire finder radar	1 shelter
USMC	MLTP	Okinawa, Japan	MMS/fire finder radar	1 shelter

Known future initiatives include OP lines for all LAVs in the Marine Corps' light attack reconnaissance battalions (Camp Pendleton, CA; Camp Lejuene, NC; Camp Williams, UT; Okinawa, Japan; and Camp Fuji, Japan) and continuing expansion of CHP within the Army Reserve.

It should be noted that each service has active ongoing corrosion protection and control (CPC) programs. In addition, at least one service—the Marine Corps—explicitly names CHP as one of its three CPC focus areas (along with its corrosion prevention products and materials program and its corrosion control and coating program).[11] There is also considerable interchange of CPC information (e.g., new technologies, lessons learned) among the services. For example, the Air Force's Corrosion Prevention Advisory Board was expanded to include other rotary wing aviation users (Army, Navy, and Coast Guard). The Joint Technology Exchange Group and the Army's annual Aviation Control Summit also include representatives from all services. Finally, the OSD-sponsored Virtual Corrosion Control Consortium (V-3C) is a promising venue for such CPC information exchange.

In general, service CPC focal points are very aware of CHP technology and its potential applications, and they consider CHP an important tool in their CPC toolbox. In addition, the consensus is there may be potential applications within the services that have not been fully exploited by CHP primarily because of funding limitations.

DoD Oversight

The National Defense Authorization Act for 2003 requires the SECDEF to "…designate a senior official or organization…for the prevention and mitigation of corrosion of military equipment and infrastructure of the Department."[12] The following are responsibilities targeted to prevention and mitigation of corrosion:

- Oversee and coordinate DoD efforts
- Develop and recommend policy guidance
- Review programs and funding levels proposed by the services
- Monitor acquisition practices
- Develop and implement a long-term strategy
- Submission of interim and long-term strategy reports

[11] MCO 4790.18A, *Corrosion Prevention and Control (CPAC)* program, December 3, 2002, pp. 2–3.

[12] House Report 107-772, National Defense Authorization Act for FY 2003, Section 2228, *Military Equipment and Infrastructure: Prevention and Mitigation of Corrosion*.

Mr. Wynne has designated Mr. Daniel J. Dunmire as DoD’s Director of Corrosion Policy and Oversight.

CONCLUSION

Each of the services is currently protecting some weapon systems and end items using humidity-controlling technology; and each service is actively pursuing other control prevention and control initiatives. However, programmatic and technical issues have precluded increased DoD CHP implementation, despite the known benefits.

Programmatic issues range from the certification process for authorizing the use of a new piece of equipment on a weapon system to the procurement process that actually gets the new equipment item into the hands of the user (although recent Small Business Innovation Research [SBIR] Phase III contract revisions have virtually eliminated this hurdle). In addition, these obstacles encompass nearly the entire Planning, Programming, and Budgeting System, and, because most of the benefits of CHP do not occur instantaneously, advocates face the challenge of resourcing initiatives without immediate results. Technical obstacles cover a number of issues, including supportability questions generally unrelated to the weapon systems, such as utility (power) availability; the design, operation, and safety of the dehumidifiers themselves; and staffing implications.

While not discounting the above issues, the most significant implementation issues may be the services’ operational requirements and logistics concepts that may not lend themselves to a wider adoption of CHP—particularly in the operational protection category. Fighter aircraft canopies remaining open while parked to minimize avionics heat build-up, cargo aircraft entrance doors that are frequently opened and closed to allow for maintenance activities, additional equipment (and power requirements) on the flight line, deployability of CHP equipment, and guidance (such as the need to “train like you fight”) all affect the methods employed by the services for corrosion prevention and control.

It is essential however, that CHP remain in the services’ CPC arsenal so that it can be fully exploited wherever appropriate. The potential for a 9-to-1 return on investment (based on the recent economic analysis of the Army Guard’s CHP program) and likelihood of increased weapon system readiness and sustainability would appear to justify the examination and resolution of potential implementation issues. With the establishment of the DoD Office for Corrosion Policy and Oversight, the timing may be right for DoD as a whole to reexamine the capabilities and benefits of CHP as part of a long-term investment strategy to protect existing and emerging weapon systems.

APPENDIX. EFFECTS OF MOISTURE AND RELATIVE HUMIDITY

The corrosive effects of moisture are well known. A 1935 British study determined that the rate of corrosion of iron and steel changes above 50 percent relative humidity (RH) from a linear to an exponential progression.[1] More recent research identified the relationship between RH and corrosion in both high-strength low-alloy and low-carbon steel, finding that the rates of corrosion are 100 to 2,000 times greater than at lower humidity.[2] Other studies have found similar results for nonferrous metals, including brass, copper, nickel, and zinc.[3]

Less apparent, but just as serious, is moisture degradation of avionics and electronics systems. For example, corrosion on gold plating used in electronics increases from 5 corrosion attacks per square centimeter at 40 percent relative humidity to over 120 attacks at 85 percent RH—a 24-fold increase. Further, a typical resistance value for nylon wire insulation at 10 percent RH is 10^{14} ohms. At 90 percent RH, that value drops to 10^{7} ohms.[4] This more than million–fold decrease in resistance can contribute to reliability problems in the extensive wiring of modern avionics and electronic systems.

In general, corrosion remains a significant problem until RH is reduced to less than 45 percent. But it should be noted that very low relative humidity, less than 25 percent, is also problematic, causing damage such as the cracking of seals.

Evaluations

Within DoD, all of the services have evaluated CHP on some of their weapon systems, including Army Cobra helicopters in Europe, Navy EP-3Es on Guam, Air Force F-4G and F-16C fighters in Europe, and Marine Corps T/AV-8Bs in North Carolina. In the early 1990s the U.S. Navy, under the aegis of the DoD Foreign Weapons Evaluation Office, evaluated CHP with operational aircraft. This 6-month test on A-6E aircraft showed a 21 percent increase in avionics mean time between failures (MTBF) and associated material savings. Table A-1 contains a list of selected CHP evaluations including service, type of weapon systems or end items evaluated, and reported results.

[1] Naval Audit Service, Audit Report 025-95, *Dehumidification of In-Service Aircraft*, February 22, 1995, p. 10.

[2] *Dry Air Technology for Defense Applications*, First ed., Munters Incentive Group, Cambridge, U.K.

[3] *Application of Dry Air Systems*, Directorate of Materiel, Royal Netherlands Army, System Major Equipment System Group, Communication Systems Division, The Hague, May 1994, p. 5.

[4] Ibid. p. 6.

Table A-1. Selected CHP Evaluations

Service	Timeframe	Type of equipment	Reported results
Navy	1993–1994	EP-3 ARIES III	▪ Avionics reliability improved 25% ▪ Intermediate-level maintenance labor reduced 40% ▪ Depot reparable costs reduces 26% ▪ Mission capability increased 4–6% ▪ Reduced MHFH 4–22% ▪ Increased MTBF 7–30% ▪ ROI achieved in 6–9 months
Marine Corps		AV-8B remanufacturing program	Compared to AMARC ▪ better environment for corrosion protection ▪ lower cost ▪ faster and cheaper return to service
Navy		Naval Engineering Leadership Program's (NELP) Pollution Prevention Equipment Program (PPEP)	▪ Stored equipment maintenance reduced by 80% ▪ Hazardous materials and hazardous waste reduced by 74% ▪ Increased equipment availability ▪ OPNAV code N-45 now funds CHP equipment and installation for Navy fleet units
ARNG (Florida)	2000	MLRS	▪ Top 10 cost drivers in the test battalion dropped 78% ▪ LRU's on the launcher are the most costly to the system and accounted for over 50% of the cost of repairs in 1999. There were zero demands for LRUs in 2000.
ARNG (Minnesota)	1997–1998	AH-1 Cobras (placed in sheltered CHP)	No preventative maintenance or inspections accomplished for 12 months After removal ▪ all controls functioned normally ▪ no leaks ▪ no corrosion ▪ pressures of all fluid systems normal
Navy FWE	1990–1991	A-6E in OP (8 aircraft)	▪ Number of failures per flight hour (for 37 items tracked) decreased 37% at the O-level and 15% overall ▪ O-level MMHs per FH decreased 41% and I-level MMHs per FH decreased 10 percent
Navy (FWE)	1990–1991	SH-60B in OP (12 helicopters, 6 test and 6 control)	Number of failures per flight hour (for 26 avionics items tracked) decreased 6% at the O-level and 86% at the I-level
Navy (FWE)	1990–1991	P-3C in OP (14 test aircraft)	Test results were inconclusive however squadron personnel reported that after their aircraft had been dehumidified for a period of time, the preflight and general maintenance requirements improved
Naval Audit Service	1995	FWE (A-6E and SH-60B) and 2d MAW (AV-8B)	▪ MC rates improved 4–6% ▪ MMHFH improved 4–22% ▪ MTBF improved 7–30%

Many foreign defense forces currently use CHP as a maintenance technology for their operational weapon systems. An industry analysis of 11 European defense forces[5] revealed that the majority has instituted CHP technology in both operational and longer-term applications. Nine nations have applied CHP to at least some of their aircraft, while seven have applied CHP to some of their ground combat vehicles. This acceptance is highlighted by Germany's decision to apply the technology to all operational military aircraft. CHP is also used on Canadian P-3 and CF-18 aircraft, Australian Blackhawk helicopters, and NATO Airborne Warning and Control System (AWACS) E-3 aircraft.

Benefits

The tangible benefits of CHP as a maintenance technology, as identified by these evaluations, can include reduced costs of ownership for weapon systems and equipment, and, at the same time, increased readiness and sustainability. For example, the Swedish Defense Force, after applying CHP as a maintenance technology, reported an overall aircraft readiness increase of 5 percent—the equivalent of an additional aircraft being permanently assigned to each fighter squadron—and an investment payback of 2.4 months. A U.S. Naval Audit Service report on CHP indicated that tests by the Navy and foreign governments showed that dehumidification is an accepted technology and has been successfully applied to operational aircraft.[6] The report added that test data and user experience indicate that CHP would increase mission capability rates by 4 to 6 percent, reduce maintenance hours per flight hour by 4 to 22 percent, and increase avionics MTBF by 7 to 30 percent.

[5] Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Sweden, Switzerland, and the United Kingdom.

[6] Naval Audit Service, *Dehumidification of In-Service Aircraft*, July 1995, p. 9.